NPOESS Conical Microwave Imager/Sounder: Warm Load Calibration Issues and Progress

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***Abstract* - The Integrated Program Office (IPO) of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) is currently engaged in developing the next-generation conically-scanned microwave radiometer known as the Conical Microwave Imager/Sounder (CMIS). CMIS heritage operational sensors are the Special Sensor Microwave/Imager (SSM/I) and its follow-on, the Special Sensor Microwave Imager Sounder (SSMIS) that are currently flying on Defense Meteorological Satellite System (DMSP) satellites. The conically-scanning CMIS sensor requires warm and cold calibration configurations stationed above the rotating canister. The exposure of the calibration configurations to non-uniform solar illuminations introduces errors in the calibration budgets. These errors were considered small for CMIS as well as for the heritage sensors. However, recent data from spaceborne radiometers indicate otherwise. Consequently, special considerations have been made in the CMIS design to ensure that overall calibration accuracy can be maintained during periods of sun exposure and sun shadow. This paper discusses mitigation of calibration errors associated with solar illumination.**

Keywords: NPOESS, CMIS, Calibration

1. INTRODUCTION

The Conical Scanning Microwave Imager/Sounder (CMIS) on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) spacecraft will produce 19 of the 55 Environmental Data Records (EDRs) required from NPOESS. The first CMIS launch is currently scheduled for 2010. The major aspects of the CMIS payload are near completion. CMIS has ‘window’ channels at 6, 10, 19, 37, 89, 166 GHz; an atmospheric temperature sounding suite utilizing 50-60 GHz; and atmospheric water vapor channels centered at 23.8 and 183.31 GHz. The CMIS sensor is a dual-reflector system having antenna apertures of ~2.1 and ~0.75 m. The two reflector antennas are oriented 180 degrees apart about the sensor spin axis. CMIS has polarimetric channels at 10, 18 and 37 GHz. In addition, CMIS includes a digital spectrometer having a suite of 40 channels centered at 60.4347 GHz. The overall sensor data rate is ~500 kb/s, the estimated mass is ~475 kg, and its power consumption is estimated to be ~426 W. The CMIS radiometer is the largest and arguably most complex sensor payload on the NPOESS satellite [1, 2].

CMIS is expected to produce roughly one third of the total number of NPOESS Environmental Data Records (EDR). Considerable attention is required to ensure that the raw data from CMIS is calibrated accurately so that CMIS EDRs are at least as good as the current requirements if not better. CMIS utilizes two-point calibration scheme. Cold sky reflector provides a low risk external calibration approach that meets the calibration requirements. The design uses a fixed reflector pointed at cold space and allows each feed to have a cold calibration with every rotation. Warm load operates between 6.4 and 193 GHz. The design uses a fixed warm load that allows each feed to have warm calibration with every rotation. The warm load design specifies a low mass magnesium base with a two layer absorbing coating. Built-in Platinum Resistance Transducers (PRTs) provide a measure of the warm load temperature that meets +/- 0.1 K temperature accuracy requirements as measured on the ground.

2. WARM LOAD PROBLEM AND CALIBRATION

At certain solar angles, the radiation from the Sun directly radiates the tips of the warm load. This causes unpredictable gradients in the radiometric temperature seen by the warm load. The gradients can occur in horizontal, vertical directions of the warm load and can be delayed in time. As a result, warm load temperature accuracy requirement of +/- 0.1K cannot be maintained throughout the orbit. In addition to direct hit by the Sun on the warm load, solar radiations are also bounced into warm load after hitting the top CMIS deck i.e. radiator. CMIS radiator is a large surface responsible for radiating heat out from CMIS systems such as receivers. The radiator is a diffused surface and is coated to be opaque to microwave radiations.

Recent analysis [3] from spaceborne radiometers shows that almost all the past and current radiometry missions’ has warm load calibration issues. The problem was not recognized because of lack of scrutiny. The goal now is to minimize these sun glint effects either by shielding the warm load and radiator from solar rays or by creating an isothermal-like environment for the area susceptible to heating by solar radiations.

3. THE MITIGATION

In a well-designed calibration system, direct illumination of the warm load tips is generally prevented by encasing the warm load within a shroud and carefully considering all possible paths of sunlight that could impinge on the warm load structure. The CMIS warm load is enclosed by a shroud and the warm load tips recessed such that these are shaded from the sun in general. To further minimize impacts to the CMIS calibration, modification of the warm load enclosure to prevent the occurrence of sun glint on the warm load tips is in progress. Reflections of the sun from the CMIS top deck are also being considered. Roughening mirror-like surfaces may reduce the effect of strong solar reflections on the warm load vertical temperature gradient.

The second mechanism potentially impacting the warm load gradients is IR emission from the CMIS top deck. The temperature of the top deck as seen by the warm load can change significantly over the course of the orbital period. Most orbits place the sensor and spacecraft into periods of sun shade and illumination. Accordingly, cyclical and sometimes rapid changes in the IR loading upon the warm load face may occur because the warm load is seeing the CMIS top deck over much of its rotational scan.

Impacts to the warm load vertical gradient from sunlight and variable IR loading can be very difficult to predict and control. In order to provide an isothermal view to warm load during the period when the load is not viewing the feedhorns, upwelling IR flux from the CMIS top deck under the path of the warm load must be held constant. Unfortunately, restrictions on the placement of the thermal radiator positioned on the top deck contribute to the difficulty of providing an isothermal environment for the warm load. However, the effect of variable IR loading on the warm load vertical temperature gradient may be reduced by enlarging the warm load tips. The electromagnetic characteristics of the warm load should not change significantly if the height-to-width ratio is held constant. A warm load cover consisting of material that blocks IR but is transparent to microwave frequencies could also stabilize the warm load vertical temperature gradient. In this case, any losses associated with the material at RF frequencies would need to be accounted for in the CMIS calibration error budget.

4. SCHEDULE

The CMIS is one of the most important sensors on board the NPOESS spacecraft scheduled to be launched in 2010. To meet this date, the detailed CMIS design is expected to be finished by 2006 upon completion of a Critical Design Review (CDR). The current phase of the CMIS development will include an Engineering Development Unit (EDU) and the first two flight units. The EDU will not have complete CMIS functionality but will allow for testing and validation of critical CMIS functions. The EDU is scheduled for completion in 2006 with the first flight delivery scheduled for the beginning of 2008. Many of the CMIS EDR Algorithms are scheduled to be complete by 2006 with all algorithms complete by 2007. This will allow sufficient time for algorithm performance analyses and conversion of science code to operational code within the NPOESS Integrated Data Processing Segment (IDPS).

5. SUMMARY

Potential calibration errors due to uncertainty in the CMIS warm load vertical temperature gradient are being addressed. The additional uncertainty is caused by two phenomena, 1) direct solar illumination of the warm load tips and 2) variability of upwelling IR incident on the warm load surface. Variations in the effective radiometric temperature of the warm load can not be adequately predicted or modeled to meet uncertainty requirements imposed on the effective warm load radiometric temperature. Accordingly, improvements to the warm load structure and improved shading from the sun are planned. These changes will reduce the associated calibration errors and enable CMIS to meet calibration accuracy requirements.

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